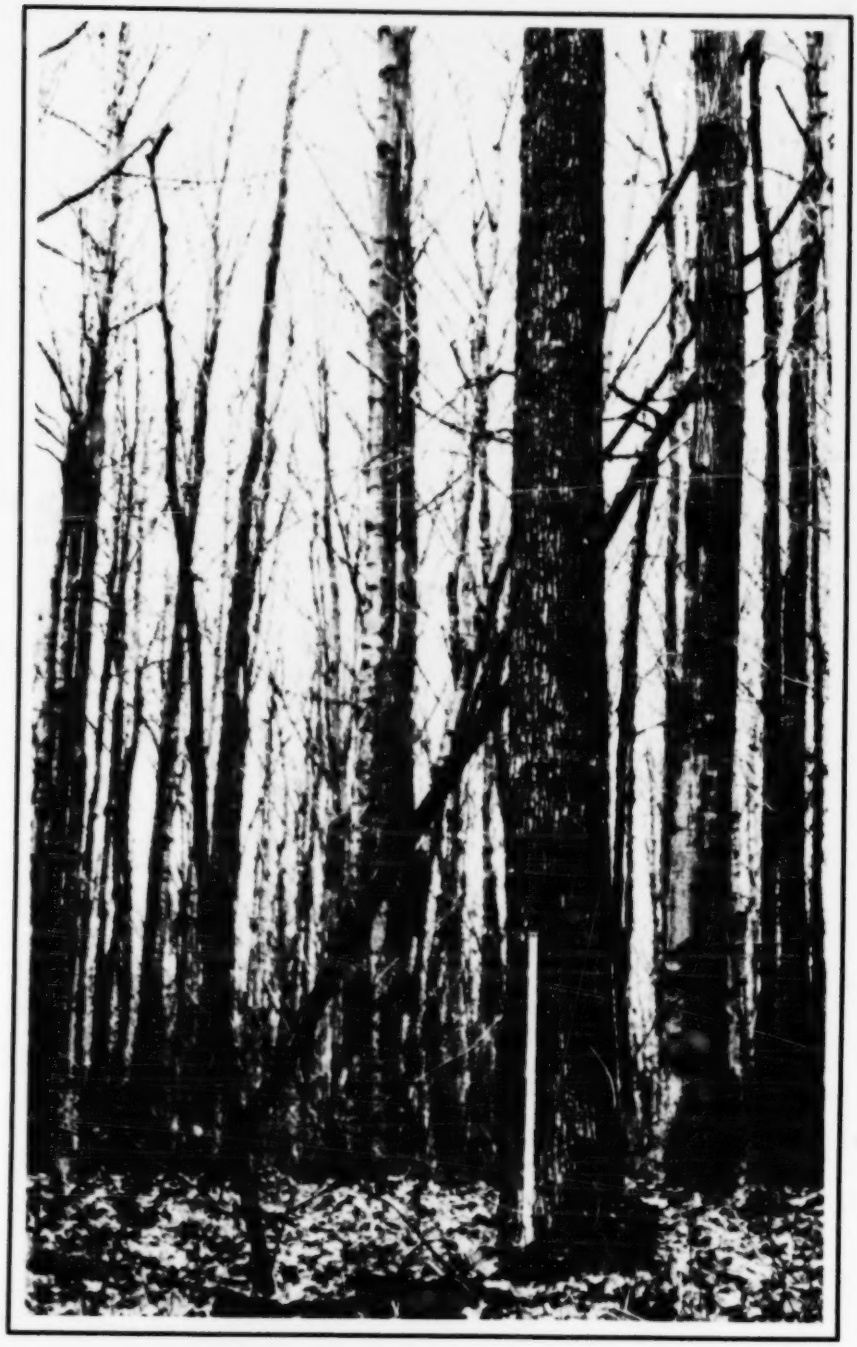
Forest Research Report No. 107

Growth Response of Basswood and Sugar Maple to an Intermediate Cutting



Ontario
Ministry of Natural Resources
Hon. Alan W. Pope
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104-06685/

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STROEMPL, G. 1983. Growth response of basswood and sugar maple to an intermediate cutting. Ont. Min. Natur. Resour., Forest Res. Rep. No. 107. 19 p.

The growth response of basswood and sugar maple to an intermediate cutting at a stand age of 52 years was followed for 12 years in a stand in Herschel Township, Ontario, where both species were represented in the intermediate and dominant canopies. Sugar maple responded positively in diameter and volume increment but basswood showed no definite increase in growth, partly as a result of crown deterioration. However, basswood exceeded sugar maple in clear bole length and log quality. The differential response to this cutting is a reflection of differences in shade tolerance between the intermediate basswood and very shade-tolerant sugar maple. Early stand tendings are he main silvicultural implications, i.e., to retain basswood's original height advantage and its high proportion throughout the rotation over the oppressive maple.

COVER PHOTO: Sugar maple-basswood in a 64-year-old stand in a proportion of 67% and 30% plus 3% other species.

INTRODUCTION

Mixed forest stands have ecological advantages over pure stands. If the use of valuable secondary species were increased, economic returns could also be improved. Basswood (Tilia americana L.) is one of these valuable secondary species in the northern hardwood forests dominated by sugar maple (Acer saccharum Marsh.), and is cut commercially in 8 forest districts in Ontario. It can produce sawlogs over a shorter rotation than many other hardwoods and it rates high in general tree quality (Godman and Brooks 1971, Tubbs 1977).

In the northern hardwood forests, the secondary associates are often treated by the same silvicultural principle as applied to the main species, sugar maple, although the former are intermediate in light requirements and the latter is very shade-tolerant. For this difference alone, secondary species, such as basswood, may need to be treated differently than sugar maple. However, to alter effectively management practices which would maintain, or even increase, the original proportion of high-quality basswood, we must first understand this species' growth response to stand disturbance.

A two-aged sugar maple-basswood stand of high quality in south-central Ontario presented a unique opportunity to examine the relative growth of both species. This stand of about 8 ha is rare because of the basswood's unusually high proportion, 37% (as a dominant species with sugar maple) by basal area.

In this study, the growth response of both species in height, diameter and volume, crown development, stem quality and regeneration, following a typical intermediate cutting, is presented and discussed.

THE STAND

The stand is located in Herschel Township, Ontario, latitude 45°09'N, longitude 78°05'W, within the Georgian Bay physiographic Site Region 5E (Hills 1960). This region is part of the Great Lakes - St. Lawrence Forest Region of Ontario (Rowe 1972), referred to as the sugar maple-yellow birch-hemlock-white pine climatic climax forest type (Hills 1960). The capability for timber production of this upland type is considered of great importance in the economy of the Bancroft Forest District (Hills 1963).

The topography of the study area is undulating with some broad summits dominated by the granitic bedrock. The soil is deep, well-drained, moderately fresh, silty sand till, quite compacted at a depth of about 1 m. The soil pH values drop from 5.6 at the surface to 4.9 in the B_1, increasing to 6.0 in the C horizon. The mean annual precipitation in this District is 823 mm with a deficit of 53 mm, of which 51 mm occur in August. The soil moisture storage level varies from 25 to 100 mm and is zero for August and September. The mean annual temperature is 4°C (Gillespie and Wicklund 1962).

The original stand, of which the older age-class is a remnant, consisted of a typical mature northern hardwood association. From the composition of the stand before the intermediate cut began, it was assumed that a heavy commercial cut was carried out in 1912. The cutover had regenerated naturally from stump sprouts and seedlings and, over the next

TABLE 1 Stand composition before and after intermediate cut in 1964

Species	Number of trees/ha	Average dbh (cm)	Average basal area (m^2/ha)
Sugar maple			
Before	724	16.6	15.8
After	531	15.4	9.8
Basswood			
Before	446	19.5	13.4
After	235	20.7	7.9
Other species			
Before	37	21.3	1.2
After	21	18.4	0.5
All			
Before	1207	17.9	30.4
After	787	17.3	18.2

50 years, developed into a two-storied stand. Before the cut in 1964, composition was 60% maple, 37% basswood and 3% other species. The density, average dbh and basal area of all trees from 12 cm to 81 cm dbh are given in Table 1.

THE CUT

In the fall of 1964, at stand age 52 (excluding the original remnants), the stand underwent an "intermediate cutting", which removed about 40% of the basal area and left a residual of 18.2 m^2/ha (Table 1). This was normally accepted by the District as the best condition for subsequent development of the stand. The cut removed all overmature and most of the defective growing stock and less desirable individuals to favour vigorous, healthy sugar maple and basswood in the dominant canopy and, particularly, in the intermediate canopy.

Attention was paid to thinning of basswood coppices to 1 or 2 stems (seldom 3 stems) per clump. Before the cut, the ratio of single trees (judged to be of seed origin) to stump-sprout trees (two or more stems per coppice) was estimated at 2:1. After the cut, the proportion of trees of apparent seed origin to trees with one or two companions was 5:1.

After the cut, the residual stand was a mixture of 67% sugar maple, 30% basswood and 3% other species (Table 1), i.e., a 7% increase in sugar maple at the expense of basswood. One year later, the crown cover ranged from 70 to 87%, as determined by "Moosehorn" readings (Robinson 1947). The front cover illustrates the stand after the cut.

MEASUREMENTS

Stem disks

In 1976, 19 sugar maple and 14 basswood trees of good quality were selected by a stratified sampling within an area of about 0.8 ha for stem analysis (Table 2). Stem disks were cut at the 0.15 m and 1.4 m heights and at every subsequent 2.5 m (or less to avoid stem irregularities), to the tip of the main stem. On the disks, radial growth over 5-year periods, starting from the bark, was measured to the nearest 1.27 mm along the major and minor diameters. These values were combined to form six 10-ring diameter intervals which cover the period 1917-1976. Heights and volumes were estimated for the same 10-year intervals. Figures 1-4, 11 and 12 represent diameters, heights and volumes related to 10-year intervals at breast height. These 10-year intervals at breast height should be distinguished from the total tree ages at stump height.

TABLE 2 Sample trees used for analysis of stem disks and cores at breast height

Species	Sample number		Average dbh (cm)		Average height (m)	
	Disks	Cores	Disks	Cores	Disks	Cores
Basswood						
Dominants	6	18	27.9	30.2	23.4	24.4
Intermediates	5	17	21.3	25.6	21.3	21.8
Suppressed	3	0	15.7	0	17.9	0
Sugar maple						
Dominants	7	8	26.7	25.9	23.0	23.8
Intermediates	7	9	18.8	23.9	18.9	21.0
Suppressed	4	0	11.9	0	15.0	0

Stem cores

In 1977, 35 basswood (15-37 cm dbh) and 17 sugar maple (15-30 cm dbh) of good quality were selected again by a stratified sampling throughout the whole stand, and bored on the north side of each stem to obtain core samples (Table 2). Measurements were made of the 1955-1977 ring widths, to the nearest 0.04 mm, to determine annual growth before and after the 1964 cut.

Suppressed trees

Data on suppressed trees (Table 2) were not plotted but relevant statistical significances are mentioned in the sections on height and diameter in the "Results".

Seed- vs. sprout-origin trees

Diameters at breast height of 134 seed-origin trees and 167 sprout-origin trees (2 or 3 or more stems per coppice), located throughout the stand, were measured in 1965 and remeasured in 1976 to compare their increments. Their crown quality was estimated visually (good, fair, poor) to determine any changes after the cut.

Fruit Production

From 1966 to 1974 fruit production of basswood was observed annually on 45 seed-origin trees and 65 sprout-trees of high quality, selected from the trees mentioned in the previous paragraph. In 1967, seed soundness was examined under 40 basswood and the number of seedlings was recorded on 80 plots 2 m^2 in size randomly located throughout the stand.

Crown area

In 1977, for an additional 62 sugar maple (16-32 cm dbh) and 77 basswood (16-37 cm dbh) in the dominant and intermediate crown canopies, located at random, the major and minor axes of their vertical projections were measured and crown areas calculated as an ellipse (πab). These were then related to the trees' diameter at breast height and to stand basal areas taken with a prism, factor 10, at each tree.

Log quality

Log quality and number of logs (4.87 m long) per standing tree were assessed on 164 sugar maple and 335 basswood (including trees from previous measurements) in the dominant and intermediate canopies and related to 4 dbh classes (8 cm intervals) of trees starting from 14 cm dbh. The smaller sample size of 164 maple is due to the smaller number of maple trees suitable for quality class sampling. From these 499 trees, 37 sugar maple and 44 basswood were selected randomly, to estimate their merchantable bole lengths, and relate them to dbh classes (3 cm intervals) from 15 cm to 36 cm dbh). The grading of standing trees was based on an ocular assessment of each tree's most conspicuous stem defects (Appendix 1).

Statistical analysis

The field data were analysed statistically to determine the significance at the 1% or 5% levels of the difference in means, including the corresponding standard errors ($\bar{x} \pm s_{\bar{x}}$), as shown in the figures. With the exception of the Chi-square test for the bole quality data (Fig. 13), the t-test was used in all other comparisons (Ott 1977). For the stem cores, the smaller sample size of 17 maples was due to the mechanical difficulties in boring maple trees. A randomly selected sample of 17 basswood was compared with the original 35. No significant difference between the two samples was found which indicated that the larger sample size was characteristic of the population and variance distributions for basswood.

RESULTS

Height

Generally, total height of dominant basswood was greater by 0.3 m than that of dominant maple throughout the six decades, but not signifi-

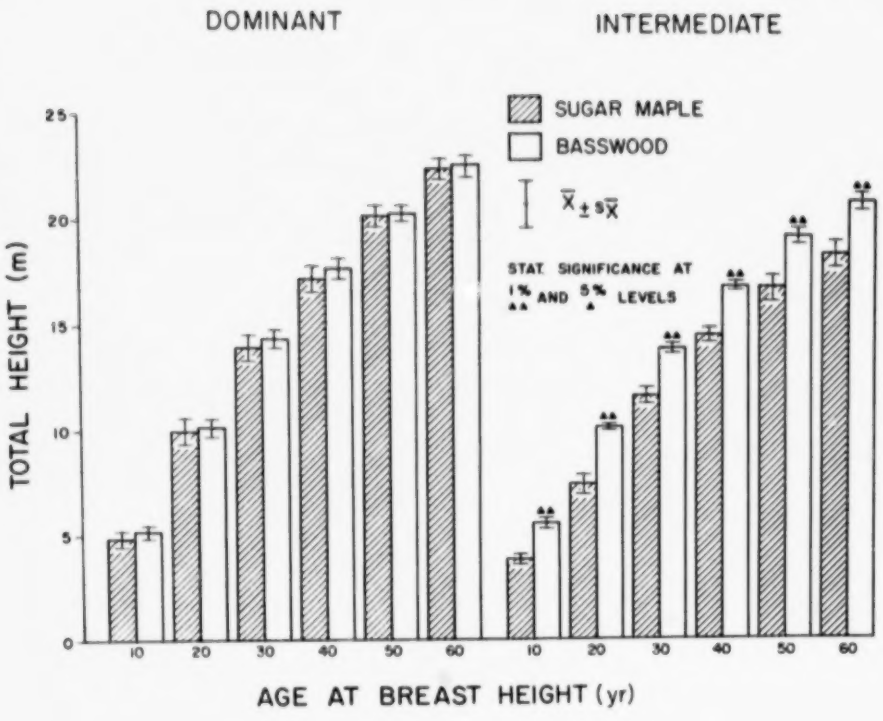

FIGURE 1. Total height-age relationships between dominant and intermediate sugar maple and basswood, derived from stem disk data. (Statistical significance is given for comparisons between species in the same age period.)

cantly at any age (Fig. 1). However, intermediate basswoods were always highly significantly taller than intermediate maples by at least 2 m.

This implies that a stratification in height growth of the maple was present from the beginning, i.e., as slow growers and fast growers. In contrast, all basswood grew more or less uniformly for the first 3-4 decades, after which some slowed in growth (Fig. 2). In spite of this slower growth rate, these, now slower-growing (intermediate) basswood, remained highly significantly taller than the slower-growing intermediate maple, because of the basswood's initially rapid height increment in the first two decades. After the cut at stand age 52 years, the only significant difference in height increment occurred in favour of suppressed maple compared to the suppressed basswood. The growth rate of all other stand components declined, but the decline was least in dominant basswood (Fig. 2).

Diameter

Both dominant and intermediate basswood had larger dbhs than dominant and intermediate maple throughout the six decades (Fig. 3). These differences were statistically highly significant most of the time. Even the intermediate basswood was larger in dbh than dominant maple for the first 4 decades.

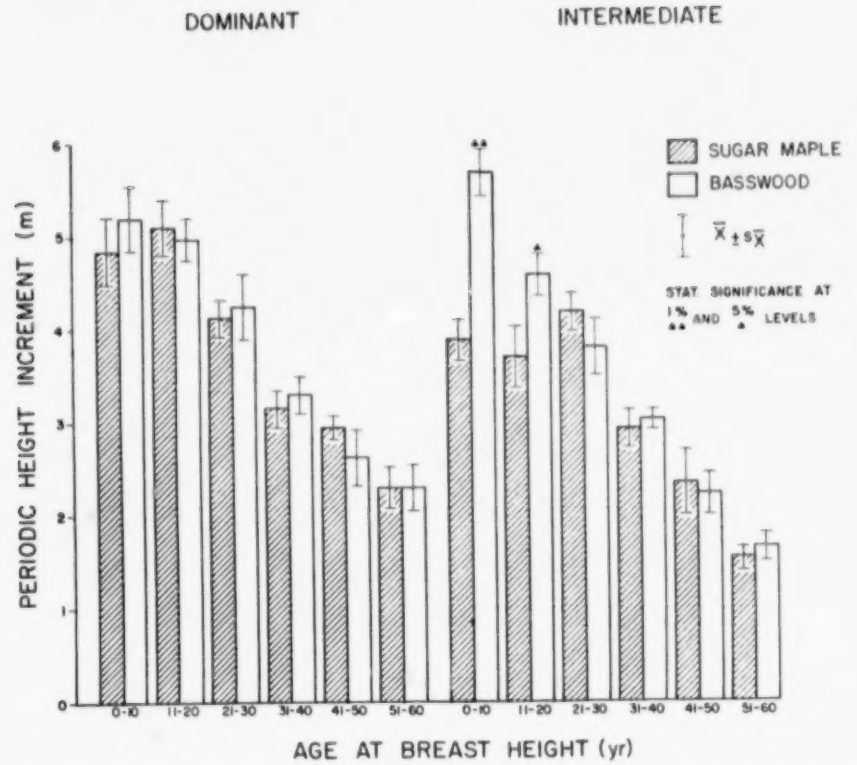

FIGURE 2. Periodic height increment relationships between dominant and intermediate sugar maple and basswood, derived from stem disk data. (Statistical significance is given for comparisons between species in the same age period.)

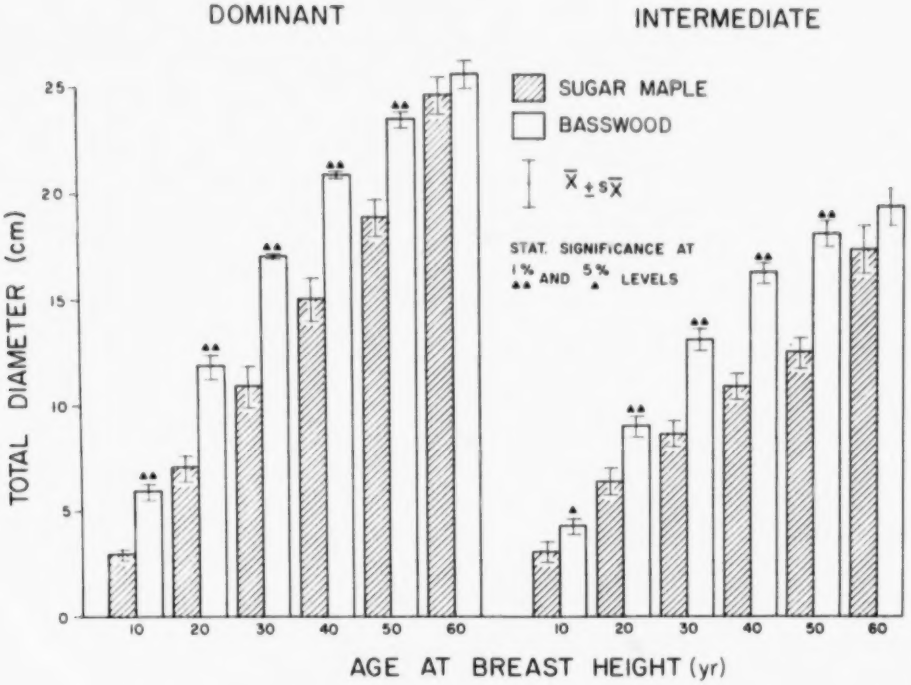

FIGURE 3. Total diameter-age relationships between dominant and intermediate sugar maple and basswood, derived from stem disk data. (Statistical significance is given for comparisons between species in the same age period.)

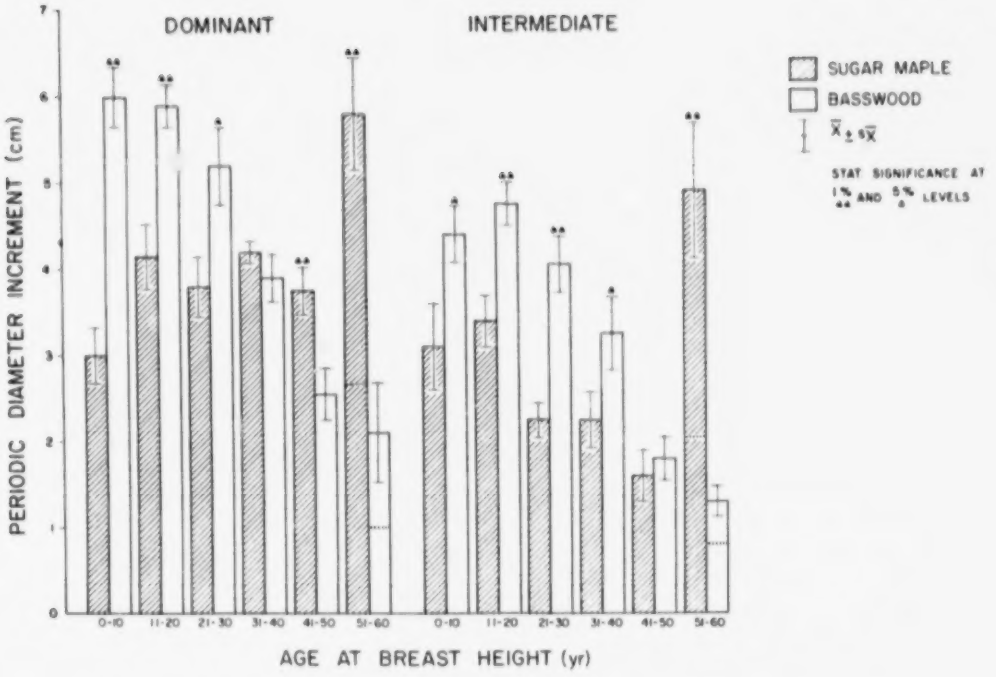

FIGURE 4. Periodic diameter increment relationships between dominant and intermediate sugar maple and basswood, derived from stem disk data. (Statistical significance is given for comparisons between species in the same age period. The broken lines in the last two bars show the increment for the first 5 years of the 6th decade in both canopies.)

For dominants, diameter increment of basswood was significantly superior to that of maple for the first 3 decades, and for the first 4 decades for intermediates (Fig. 4). The increment declined from its maximum more rapidly in basswood than in maple. While it continued to decline in basswood after the cut, diameter increment increased highly significantly in maple. The suppressed maple also produced a highly significantly better diameter increment than the suppressed basswood after the cut.

Figure 5 shows the average annual ring width at breast height 10 years before the cut (1955-64) and 13 years after the cut (1965-77), based on tree increment core data. Only dominant maple showed a consistently increasing ring width for the last 6 years before the cut, but not significantly better compared to other stand components. In maple, ring widths reached a maximum 4-5 years after the cut and then declined slowly, but remained wider than the pre-cut widths. In basswood, the maximum was reached 3 years after the cut and dropped sharply, recovering slightly thereafter, but remained highly significantly below that of the maple. The positive effect of the cut at this stand age was much more pronounced in maple, particularly the intermediates, than in basswood.

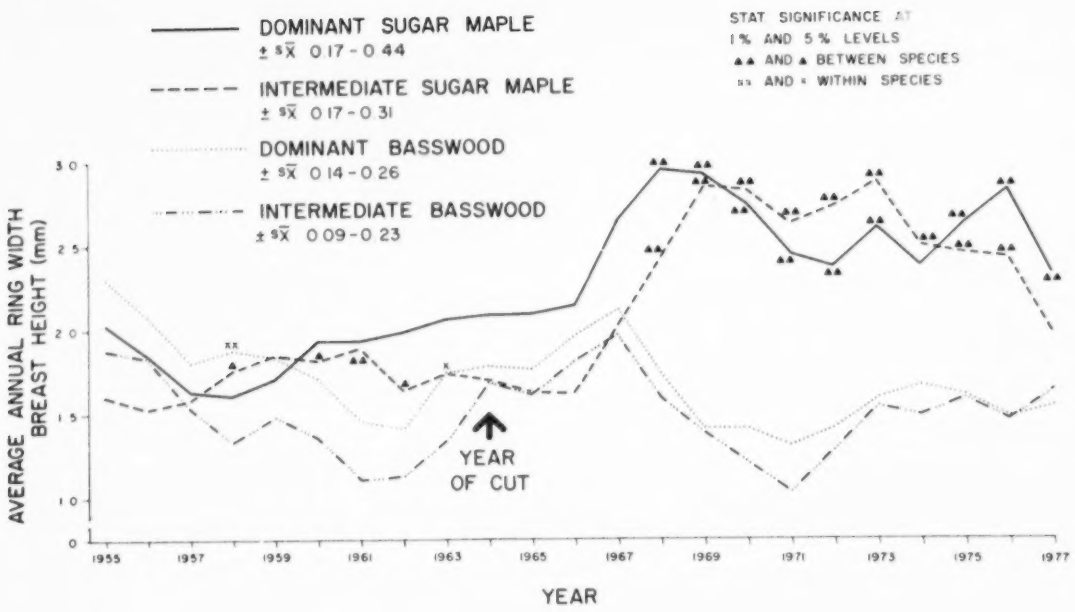

FIGURE 5. Average annual ring width at breast height of dominant and intermediate sugar maple and basswood for 10 years before and 13 years after an intermediate cut 1964, derived from core increment data. (The range of standard errors is given for each stand component for the period from 1955 to 1977.)

Crown quality and crown area

Crown deterioration of basswood was evident. The proportion of trees with crowns estimated as good, fair and poor, respectively, was 43%, 52% and 5% one year immediately after the cut, but 31%, 56% and 13%, 12 years after the cut. After the cut, in basswood, there was a consistent decrease in ring width in all crown classes, while in maple it increased significantly, especially in the smaller diameter trees (15-23 cm). Thus the intermediate crown class of maple benefited most from the crown release. Good crown conditions of an intermediate basswood and intermediate maple 12 years after the cut are shown in Figures 6 and 7. Crown weakening of an intermediate basswood, as was frequently found, is shown in Figure 8.

Thirteen years after the cut, crown areas of both species were smallest in locations of greatest basal areas (Fig. 9); sugar maple showed an average of 47% (39-64%) more crown area per tree than basswood on locations with basal areas from 18 m^2 to 39 m^2, in both crown canopies. Maple trees had also a significantly greater crown area than basswood in all diameter classes (Fig. 10); generally, the crown area of trees increased significantly as tree diameter increased, except for maple in the largest diameter class.

Crown deterioration may have been further influenced by the presence of the basswood looper (Erannis tiliaria Harr.) and leaf roller (Pantographa limata G. & R.) in the years following the cut, with one severe

FIGURE 6. Good crown development of intermediate basswood after release.

FIGURE 7. Good crown development of intermediate sugar maple after release.

FIGURE 8. Crown weakening of intermediate basswood after release.

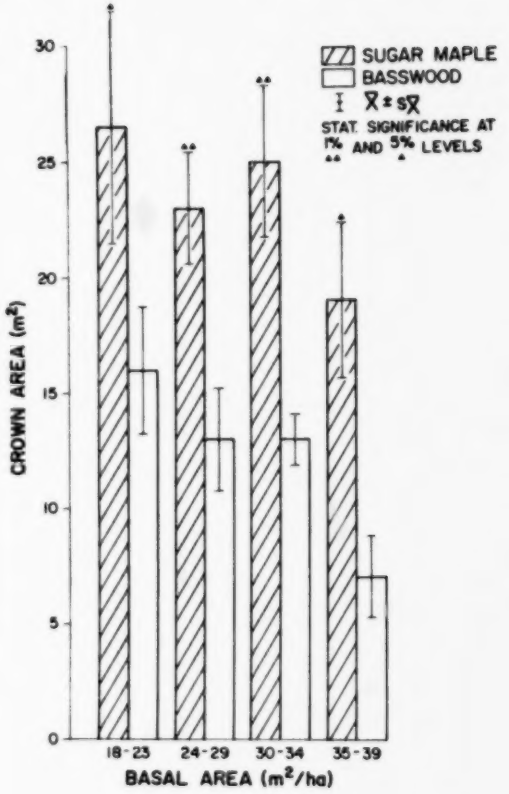

FIGURE 9. Tree crown projection area-stand basal area relationships between sugar maple and basswood 13 years after the intermediate cut. (Statistical significance is given for comparisons between species in the same basal area range.)

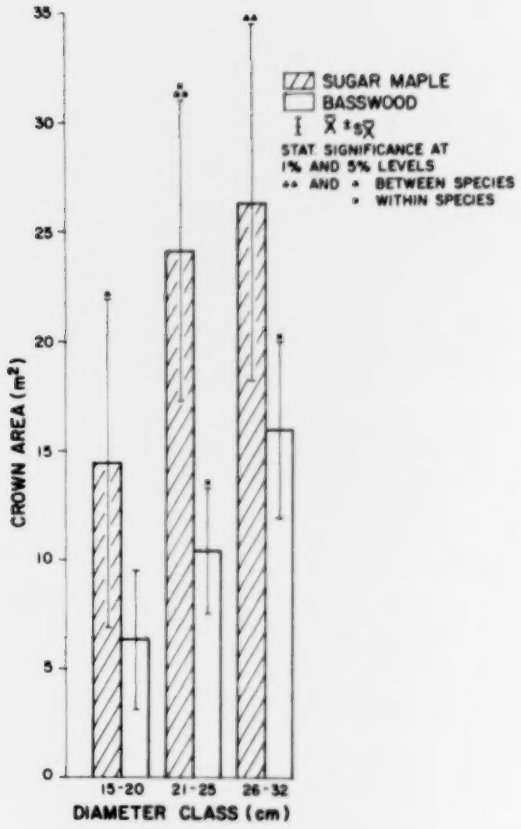

FIGURE 10. Tree crown projection area-tree diameter relationships between sugar maple and basswood 13 years after the intermediate cut. (Statistical significance is given for comparisons between species in the same diameter class, and within species in the adjoining diameter class.)

infestation recorded in 1969, in the same Township where the stand is located (Anon. 1969). Since the basswood ring width growth was already declining immediately after the cut, it is possible that there may have been an unrecorded insect infestation prior to 1969.

Volume

The total volume of dominant basswood was significantly better than that of dominant maple throughout the 6 decades, and even the intermediate basswood was superior to dominant maple for 4 decades (Fig. 11). The volume increment in basswood reached a maximum in the 5th decade in dominants and in the 4th decade in intermediates, declining after the cut (Fig. 12). In maple, volume increment increased fairly uniformly during the first 5 decades and accelerated markedly after the cut.

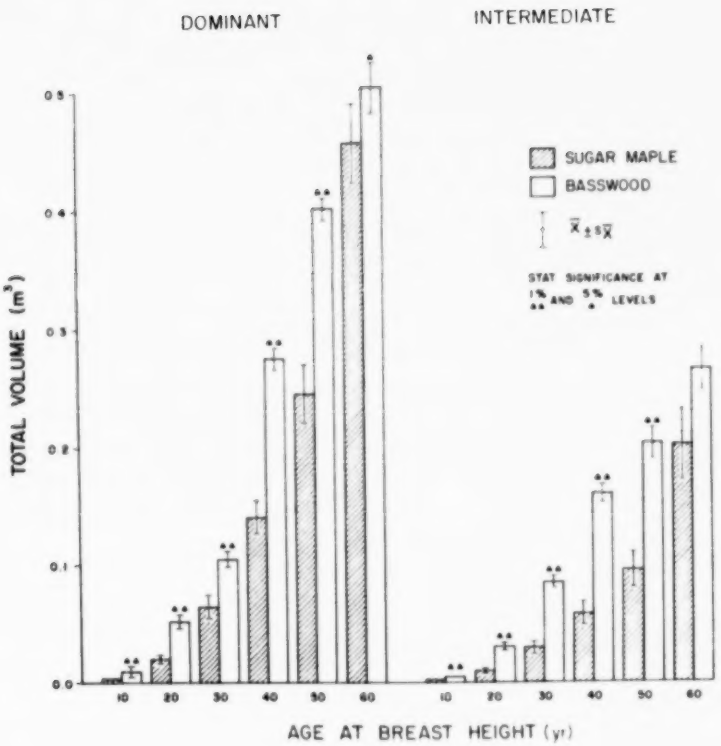

FIGURE 11. Total volume-age relationships between dominant and intermediate sugar maple and basswood, derived from stem disk data. (Statistical significance is given for comparisons between species in the same age period. The missing standard errors were too small for plotting.)

Stump sprouts of basswood

Results of the diameter measurement of the seed- vs. sprout-origin trees showed that in the 11-year period between measurements:

1/ The increment of either sprouts in a V-type connection was the same or greater by up to 10% than that of single trees of seed origin.
2/ The increment of one sprout whose companion(s) had been cut was the same or greater by up to 10% than that of single trees of seed origin.
3/ The increment of one sprout growing with several others in a coppice was smaller by 30-40% than that of one sprout in (1), (2) or single trees of seed origin.

Clear bole and log quality

There was a greater percentage of basswood trees than maple trees in bole quality class one and class two (Fig. 13). There was also a greater percentage of basswood trees with two and two and one-half 4.87 m (16 ft) logs than maple trees, although maple had a greater proportion of trees in the largest diameter class 37 cm+. The greatest number of logs was

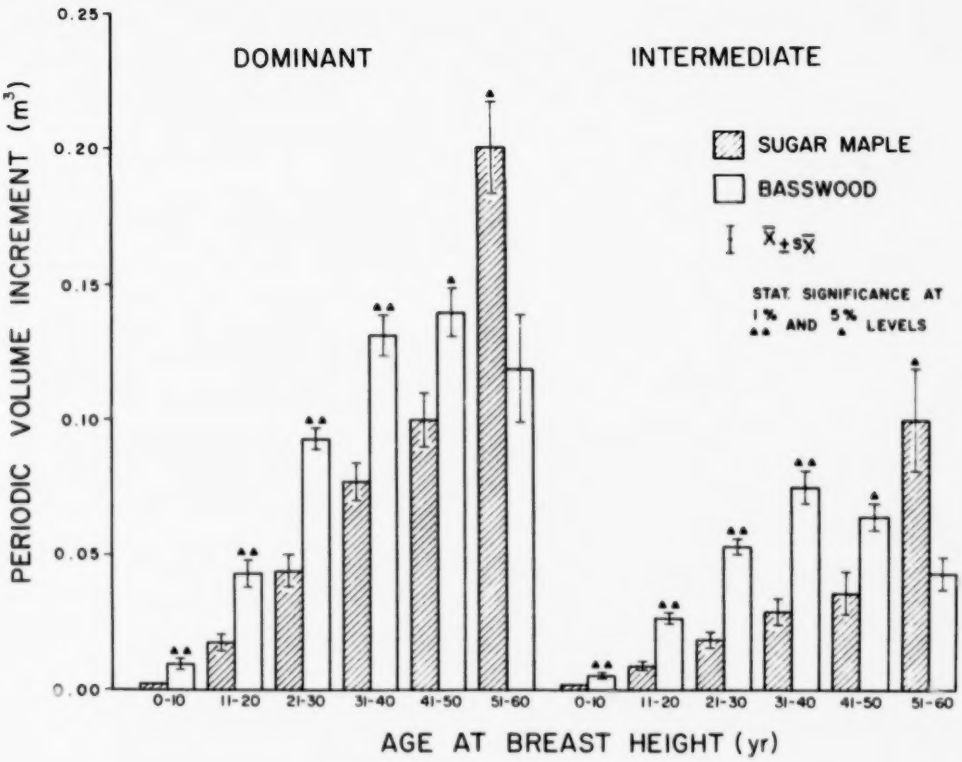

FIGURE 12. Periodic volume increment relationships between dominant and intermediate sugar maple and basswood, derived from stem disk data. (Statistical significance is given for comparisons between species in the same age period. The missing standard errors were too small for plotting.)

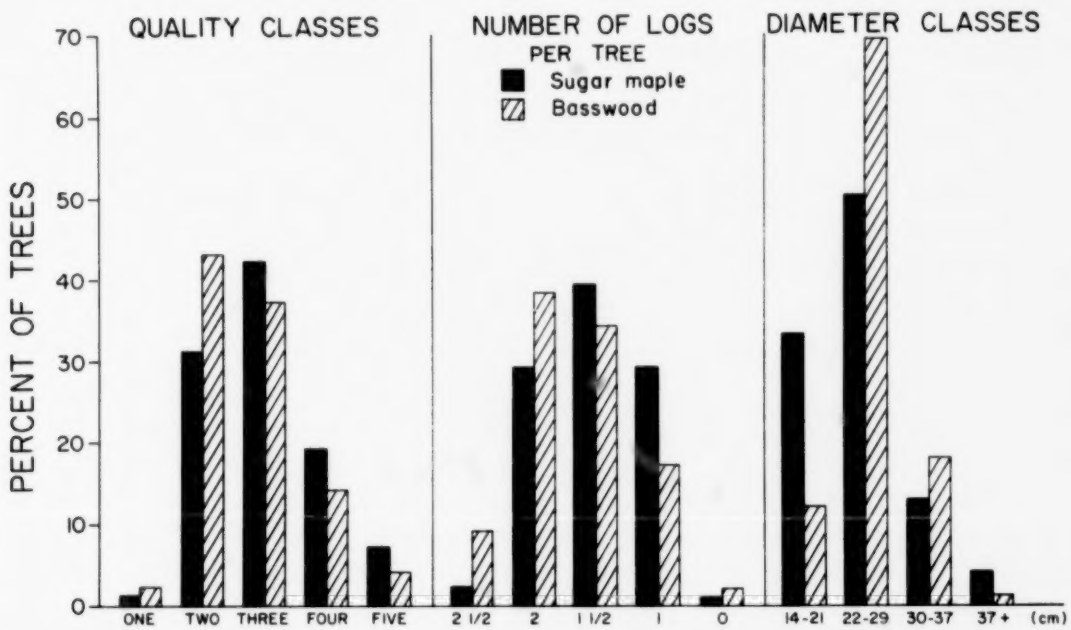

FIGURE 13. Log quality, number of logs per tree and diameter relationships between sugar maple and basswood. (Statistical significance was calculated and described in the text.)

FIGURE 14. Dominant basswood of quality class 1, 27 m in height, 35 cm in diameter and containing three 4.87-m merchantable logs. Note the relatively small crown.

contained in trees in the middle-range diameter class (22-29 cm) representing 50% and 69% of all maple and basswood trees, respectively.

The average merchantable bole length was 13.4 m in basswood and 10.5 m in maple. This relationship was statistically significant. However, in neither species was the relationship between tree diameter and bole length significant.

Figure 14 illustrates a dominant basswood of quality class one containing three merchantable logs.

Fruit production and regeneration

Crown release as a result of the intermediate cut did not induce an appreciable fruit production of basswood. In the first and second year after the cut 34% and 24% of the trees, respectively, produced fruit, but the quantity per tree was very low; in the third year only 4.8% of the fruit found on the ground contained sound seed. None of the trees produced fruit in the following five years. Later, only a few dominant trees produced some fruit which was destroyed by rodents on the ground. The incidence of the basswood looper and leaf roller in the years following the cut (Anon. 1969) could have affected fruit production. This is not surprising, because drastic opening of the stand through thinning usually creates favourable conditions for a subsequent insect attack (Craighead 1950).

Sugar maple advanced reproduction was present before the intermediate cut as is often the case in hardwood stands. After the cut, the reproduction became dense in small openings created by the removal of overmature wolf trees. Initially, there were a few basswood seedlings but none was found four years after the cut. Stump sprouts of basswood developed but most perished six years after the establishment, probably due to insufficient sunlight; those remaining were of very slow growth.

DISCUSSION AND RECOMMENDATION

We must accept the likelihood of great variation in growth among any species as well as among trees of the same species on an apparently homogeneous microsite (Burns and White 1930). This certainly applies to the northern hardwood forests where secondary species grow in competition with the predominant sugar maple.

In the Herschel stand, height growth of basswood began to decrease immediately after culmination in the 1st decade. Diameter growth also decreased significantly after the 2nd decade, primarily as a consequence of maple competition. Crowding of basswood in clumps was likely another reason why some of the dominants slowed in height growth after the 2nd decade. In contrast, height and diameter growth of most maple increased for the first two decades before culmination in the 2nd decade, except the height increment of intermediate maples which culminated only in the 3rd decade.

It is at a very early age in stand development that the species intermediate in light requirement, including basswood, benefit most from a stand tending operation in even-aged second-growth stands (Conover and Ralston 1959, Ffolliott 1959, Gingrich 1971, Jemison and Hepting 1949). In basswood, it is also advantageous to thin multi-stemmed clumps to at

most two stems to equal or better the diameter increment of trees of seed origin. Two companion sprout-trees should be left as one unit because cutting of the one did not improve diameter increment of the other.

An earlier cleaning at Herschel, when the stand first reached a basal area of about 20 m^2/ha rather than 35 m^2/ha and a corresponding difference in crown area of about 40% rather than 65% between the two species (Fig. 9), would have stimulated later a better growth on a greater number of basswood. The objective would be to retain the earlier height advantage which basswood attained and to keep this species in a dominant position later.

Crown release in a stand will not necessarily bring the desired result to all species. In the Herschel stand, this was evidenced by diameter growth of the maple increasing or remaining unchanged from the 3rd to the 4th decade, with basswood growth dropping sharply (Fig. 4). An undetermined natural crown disturbance before the end of the 3rd decade may have been one reason. Moreover, the improvement cut at age 52 years, a much more severe crown disturbance, again gave maple a strong advantage over basswood in diameter growth response (Fig. 4). Crown deterioration of basswood after the cut, to a certain degree coupled with the insect attack, was also advantageous to maple. The advantages attained by basswood early in life, i.e., total height growth and clear bole length, were retained. The detrimental aspect was that, even by the 3rd decade, the basswood crowns may have become too small to allow improved diameter growth to take place. Basswood in closed stands generally has a shorter and narrower crown than sugar maple (Frothingham 1915, Godman and Tubbs 1973).

The improvement cut in the Herschel stand was an attempt to avoid high-grading resulting from conventional commercial operations in tolerant hardwoods. The cut converted the stand to a more manageable single-aged canopy by the removal of the older overstory. For similar stands, Tubbs (1977) has presented a diagram indicating desirable stocking levels for various proportions of basswood. According to that diagram, the Herschel stand, with 30% basswood and a residual basal area of 18 m^2/ha (Table 1), should have been left with 656 trees/ha instead of 787 trees/ha.

In a natural, undisturbed, mixed hardwood stand maple will take over and gradually eliminate basswood (Zon and Scholz 1929). Therefore, interference must come within the first two decades of stand establishment to restrain this process. In Herschel, even a likely minor natural crown disturbance after the 2nd decade simply assisted the decline in growth of the sensitive basswood. The improvement cut that followed in the 5th decade reduced the number of basswood drastically as well as the proportion basswood to maple in the stand. At the same time, the response of the remaining basswood was minimal, because their crowns had already been so reduced that they could not respond.

As it stands, handling of this mixture has been to the benefit of the maple component. The chance to keep basswood in its original proportion or to regenerate it naturally, partly now or completely in the next rotation, has been missed. This is due to lack of recognition of the difference in the growth response between basswood and maple from early youth, as well as the regeneration requirement as a consequence of a long developmental "process" for basswood rather than an "act" of one cutting for maple.

There are three considerations for future management. Firstly, if the stand is to be left untouched until harvest cutting, there will be little chance for basswood to retain itself in the next rotation. Secondly, intermediate cuttings to the levels already applied, or as suggested for maximum growth (Tubbs 1977), will continue to be detrimental to the basswood component in the present stand. Thirdly, to maintain basswood in a significant proportion, the stand basal area would have to be reduced below the level suggested for optimal yield at the expense of some good maple. This will require costly clearcutting of small openings at the end of the rotation and planting of genetically superior basswood stock, followed by repeated cutting back of the competing maple.

The most logical approach in similar mixtures would be to interfere before stand age 20 years to encourage height growth of a maximum number of desirable basswood. At the same time diameter increment and volume production of selected "candidate" maple would be accelerated. This may apply to other valuable intermediate species associated with sugar maple.

Early interferences are particularly important because they are most influen'ial in the development of a commercial high-quality mixed-species stand. Later interferences will then gradually increase the number of potentially dominant trees, and the possibilities for maximum quality selection of both species would also increase.

ACKNOWLEDGEMENT

The author is greatly indebted to the official reviewers of the Institute; to A.F. Beckwith for contributing mensurational data and assisting with many sections of the manuscript; to Dr. D. Burger for the criticism; to B.J. Graham and S. Kostelnyj for the statistical analyses; and to T.J. Taylor for the field work and voluminous data compilations. Special thanks are extended to Miss Jean Robinson for the photographic work.

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APPENDIX 1

Log Quality Description

Log Quality One	Trees with two and more straight, branchless, 4.87 m (16 ft) logs free of any visible defect or rot.
Log Quality Two	Trees with two straight, branchless, rot-free logs. The top log may contain one branch stub about 7.5 cm in diameter or less, slight knot, or closed seam with no evidence of decay.
Log Quality Three	Trees with one or two straight, branchless, rot-free logs. The top of the log may contain one branch stub greater than about 7.5 cm diameter, slight crooks, slight knot and bark distortion, or open seam with evidence of decay.
Log Quality Four	Trees with one straight, branchless, rot-free log. The top of the log may contain one branch stub greater than about 7.5 cm diameter, severe crook, severe knot and bark distortion, or open seam with evidence of decay.
Log Quality Five	Cull trees not suitable as sawtimber.

Stem Defects Description

Defects, from most to least frequent, estimated on standing trees, were:

Slight crook, one per stem - log will produce lumber <4.87 m (16 ft) and >3.65 m (12 ft).
Slight crooks, two and more.
Severe crook - will produce waste when log cut to lumber.
Slight knot and bark distortion - overgrown branch or bark distortion externally sound.
Severe knot and bark distortion - partly overgrown branch or bark distortion with evidence of decay but log mostly merchantable.
Visible rot - advanced stage of decay.
Closed seam - no evidence of decay, externally sound.
Open seam - evidence of decay but log mostly merchantable.
Fork - no homogenous trunk above second log.

5614-2
1k P.R., 83/07/01
ISBN 0-7743-8206-6
ISSN 0301-3924